Water

P.E.I.'s MOST PRECIOUS RESOURCE

GROUNDWATER RESOURCES EVALUATION

TIGNISH

THE CANADA – PRINCE EDWARD ISLAND
WATER MANAGEMENT AGREEMENT

Environment Canada Environnement Canada

Prince Edward Island
Department of the Environment

GROUNDWATER RESOURCES EVALUATION

TIGNISH

92-07518/

Groundwater Resources Evaluation - Tignish

Executive Summary

A test drilling and pump testing program as well as a review of the available hydrogeological data for the Community of Tignish was conducted during 1989 and 1990 to document the current status of groundwater resources in the community. The results of this investigation indicate that in terms of quantity, domestic water supplies can be developed virtually anywhere in the community but the development of high capacity wells, with some exceptions has proved more difficult .

Natural water quality in the area is generally good however in parts of central Tignish groundwater quality has been seriously impaired by man made influences, most notably by two serious petroleum spills and one incident involving contamination by the herbicide Dinoseb.

Test drilling in the northern part of the community has identified a sufficient quantity of groundwater to meet all the communities current needs, with some room for expansion. These wells now supply the central water system servicing the central portion of the community in the vicinity of the dinoseb contamination as well as some area's previously affected by petroleum contamination. On-site water supplies outside these areas should continue to provide good service although some periodic monitoring of the extent of contaminant plumes should be undertaken to ensure that water quality in non - serviced areas has not deteriorated.

The establishment of effective well field protection measures will be an important element of wise groundwater management and a heightened awareness of water quality issues in general will help ensure the preservation of this resource.

Acknowledgments

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Groundwater Resources Evaluation - TIGNISH

1. Introduction

This report documents the findings one of a series of studies, conducted as a part of the groundwater resource evaluation project under the Canada - P.E.I. Water Management Agreement. These studies are aimed at evaluating the available quantity and quality of groundwater resources in selected communities across the Island.

2. Geography

2.1 Physical Geography

Tignish is located at the western end of Prince Edward Island, approximately 160 km from Charlottetown. Surface relief is generally flat to gently undulating, with the Tignish River forming the southern boundary of the community. The community covers an area of approximately 673 ha, with the land sloping very gently from an elevation of 21 m in the north to near sea level along the Tignish River in the south. The Tignish River is the only significant surface water body in the community and drains an area of approximately 4400 ha. Most of the land in the community are well drained although there are some low lying swampy areas in the north east sections of the community and in the south along the river.

2.2 Cultural Geography

The population of Tignish according to the 1986 Census is 960, and has declined slightly (2.2%) since 1981. With an area of 6.7 Km2 the population density is estimated to be approximately 143 persons per square kilometer. Fishing, farming, and service industries provide most of the employment in the area, and the community of Tignish is one of the main centers in the northern part of west Prince County.

3. Geology

3.1 Surficial Geology

Overburden in the Tignish area is primarily composed of a sandy, compact ground moraine which is quite likely derived locally from underlying bedrock. In test pits excavated into bedrock, the bedrock / till contact is often indistinct with the top meter or so of bedrock being highly weathered, with only remnants of the original primary stratification being preserved in

the bedrock. This till is generally fairly thin (average of 3 m) and correlation of depth to bedrock between adjacent test pits suggests that the underlying bedrock surface is somewhat irregular.

Soils in the community are generally moderately coarse textured, and acidic with good to moderate surface drainage and predominantly good to moderate subsoil permeability, although some soils exhibit moderate to slow subsoil permeability.

3.2 Bedrock Geology

Bedrock consists of Upper Pennsylvanian to Lower Permian sedimentary strata of megacyclic sequence II (van de Poll, 1981). These strata are believed to slightly younger age equivalents to the Pictou Group sediments found throughout the Maritime provinces, and are composed primarily of sandstone, interbedded with claystone, siltstone and locally a relatively thin basal conglomerate. The environment of deposition of the sediments is believed to be fluvial in origin and their stratigraphy is characterized by rapid lateral facies changes associated with recurring cycles of fluvial sedimentation.

Well drillers reports from wells constructed in the community indicate a stratigraphy dominated by sandstone interbedded with lesser amounts of claystone, with some wells being completed almost entirely in sandstone.

4. Hydrogeology

4.1 Existing Well Data

The P.E.I. Department of the Environment has records for approximately 115 domestic wells drilled in the community since the early 1970's. In addition there have been at least 9 test wells constructed in the community in the past 2 years, mostly as part of water quality investigations. The average depth for domestic wells in the community is 20 m with a maximum depth of 47 m and some older wells as shallow as 6.1 m. The average length of casing in these wells is 10.6 m with a maximum length of 28 m and a minimum of 2.5 m. Average well yield for normal domestic wells, as reported on the well drillers records is 0.57 litres per second (L/sec.) with a range of 0.38 L/sec. to 0.91 L/sec.

To make more meaningful the well yield data from the well drillers reports, the well depth or more precisely the saturated portion of the aquifer penetrated by individual wells must be taken into account. As is common on P.E.I., individual aquifers are often difficult to identify, especially as the flow of water through fractures is probably more significant than

primary porosity in determining hydraulic conductivity (Francis, 1989). For these reasons the entire saturated thickness of sediments penetrated by well can be approximated as a single semi- confined aquifer.

All other factors being equal, a deeper well with a greater depth of open hole below the water table would be expected to yield a greater quantity of water than a shallower well. To evaluate the water yielding characteristics of the aquifer then, it is useful to take into account the saturated thickness (water bearing portion) of each well when considering well yield.

As a measure of aquifer yield then, the yield per metre of saturated thickness penetrated, for each well has been calculated. The average yield per metre (L/sec./m) of saturated thickness is 0.072 ranging from a minimum of 0.03 to a maximum of 0.28 L/sec./m. This would mean that on average a well 30 m deep with a static water level of 12 m would be expected to yield approximately 1.3 L/sec. The test holes drilled under this program had yields/ m of saturated thickness of 0.11 and 0.12 L/sec./m respectively for test holes TIG-1 and TIG-2.

In addition to the information from well drillers reports, there have been several pump tests conducted on wells within the community, with varying degrees of sophistication. Test drilling and pump testing activities conducted as a part of this project will be discussed in some detail in the following section. In addition to this there have been pump tests conducted on wells at the new tignish elementary school, the old fire hall (currently the community office, and at the new fire hall. The well at the old fire hall presently supplies water for a temporary water system servicing a part of the community which has experienced water quality problems in the past 2 years.

Tignish Elementary School

The well at the Tignish Elementary school was constructed in 1988. This well was pumped at a rate of 1.7 L/sec. for a period of 6 hours. The resulting drawdown at the end of the test was 1.8 m. The transmissibility value calculated for the aquifer using the Jacob staight line method is 32 m^2/day. It should be noted that as this value was calculated from pumping well data only, thus well losses may constitute a significant portion of the total head losses during the test, and a higher T value may be more representative of the aquifer. No value for storativity could be calculated as observation well data were not collected.

It is interesting to note that the well drillers report for the nearby senior citizens complex records a well yield of 3.8 L/sec. after a 30 minute test. Unfortunately no pump test data is available for this well. Nonetheless with this fact in mind plus the fact that the drawdown in the elementary school well was only 1.8 m at the end of the test , it is possible that this latter well would be capable of yielding considerably more than the 1.7 L/sec. at which it was tested.

Old Fire Hall Well.

The well at the former Fire Hall was constructed in 1983 and is of 10 cm diameter, 59 m deep and cased to a depth of 8.2 m. This well was subjected to a step drawdown test with 30 minute steps at rates of 1.9, 3.8, and 5.7 L/sec. During these steps drawdowns of 1.2, 4.9, and 9.3 m were recorded. The specific capacities for each of these steps were 1.5, 0.77, and 0.6 L/sec./m respectively. Although drawdown measurements were made in an observation well, no constant rate test was performed and reliable transmissibility and storativity values can be calculated from this data. A total of only 0.63 m of drawdown was recorded in the observation well, at the end of one and a half hours, although unfortunately the distance to the pumping well was not recorded.

4.2 Test Drilling and Pump Testing

To further evaluate the aquifer characteristics in the area, and to determine if a suitable quantity of good quality water could be found which would be capable of supplying a central water system in the community, a test drilling and pump testing program was conducted.

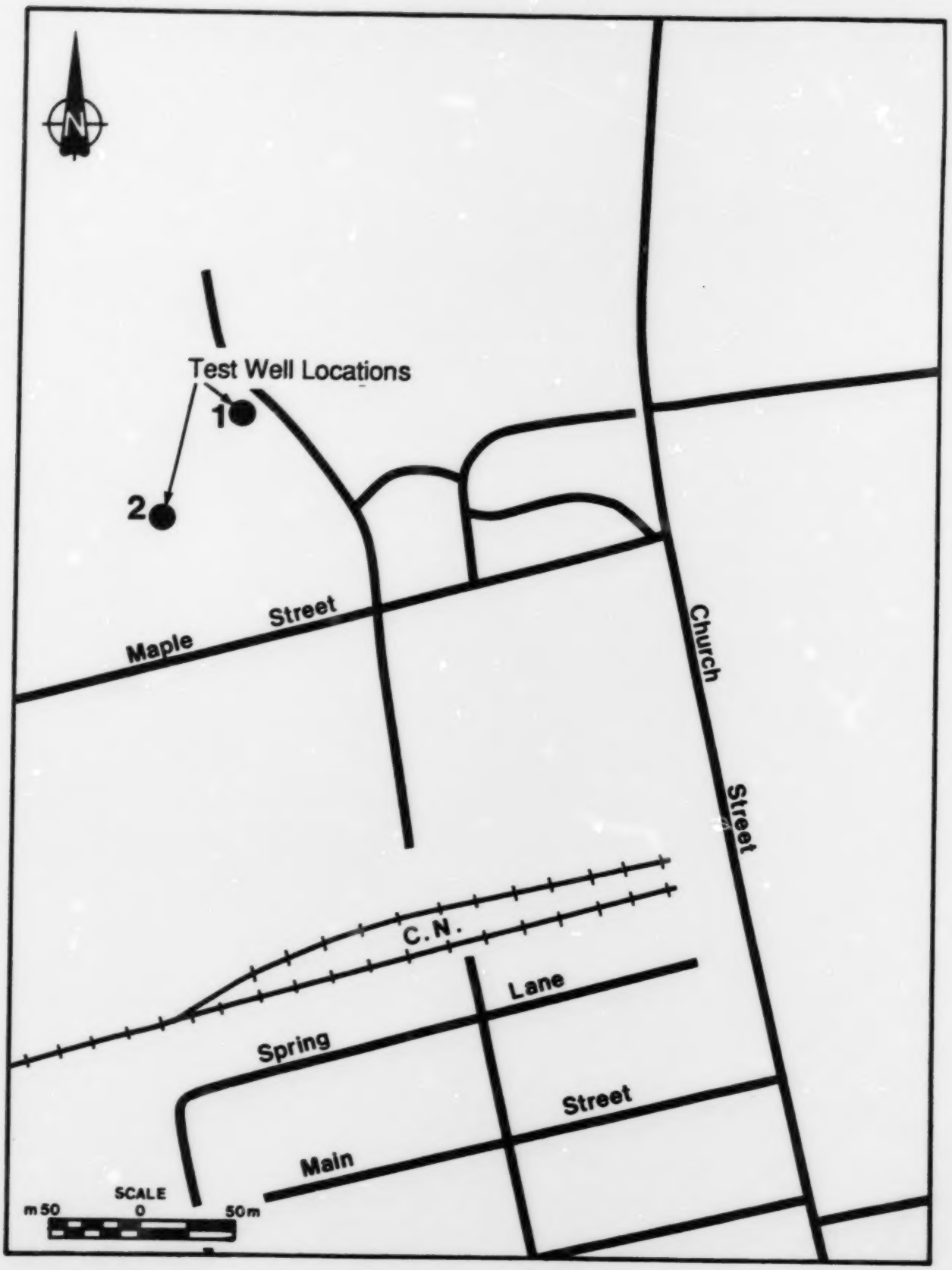
4.2.1 Site Selection

In selected a site for test drilling, three criteria were considered; the likelihood of obtaining a sufficient volume of water, the likely hood that the water would be of good quality, and the ease with which land use in the vicinity of the wells could be managed so that appropriate well field protection could be established.

A review of existing well data did indicate that one area was more promising that any other area in terms of finding a suitable location for "higher capacity" wells. Higher than normally yields were reported for the wells at the former fire hall, the senior citizens home and Tignish Elementary School, although this may be primarily a function of the demand for water at these establishments rather that particularly favorable aquifer characteristics. Attempts to develop high capacity wells at the new fire hall near the south end of Church Street have so far been relatively unsuccessful.

The most important constraint for well location in the community was groundwater quality. As will be discussed at some length in a separate section of this report, the central portion of the community has been subjected to a variety of incidences of groundwater contamination over the past 2 to 3 decades, thus concern over groundwater quality played the most significant part in the selection for the test wells. Generally speaking the northern portion of Tignish has less commercial and industrial development, and has not had a history of any serious groundwater contamination.

Figure 1


N
Test Well Locations
1
2
Maple Street
Church Street
C.N.
Lane
Spring
Street
Main
SCALE
m 50
0
50m

Finally, it was felt that the test drilling site should be in an area where some form of well field protection could be implemented, particularly in a case where these well's in all likely hood may eventually become the source of supply for a central water system, servicing at least some portion of the community.

For these reasons, the land occupied by St. Judes Catholic Church was chosen for testing. This site has had a land use history which is for the most part compatible with good water quality and future land use is not expected to change appreciably in the foreseeable future. Furthermore, the property is large enough to afford a reasonable degree of protection to the wells should they be used as production wells, without requiring extensive changes to existing zoning by-laws. The location of the two test wells is indicated on Figure 1.

4.2.2 Test Drilling

Each of the two test wells were drilled by cable tool rig to a depth of 61 m and are 15 cm in diameter. The wells were drilled approximately 55 m apart, and each well is cased to a depth of 12 m, with the lower portion of the annular space between the casing and the well bore sealed with bentonite, and the remaining annular space being back filled with clean native material. Samples were collected during the construction of the wells at 1.5 m intervals and logged for lithology. Following completion, the wells were logged with a natural gamma tool and flow meter. The lithological and gamma logs for each well is presented in Figure 2. Static water levels in well TIG-1 and TIG-2 were 8 m and 6.54 m below the top of the casing respectively at the completion of each well.

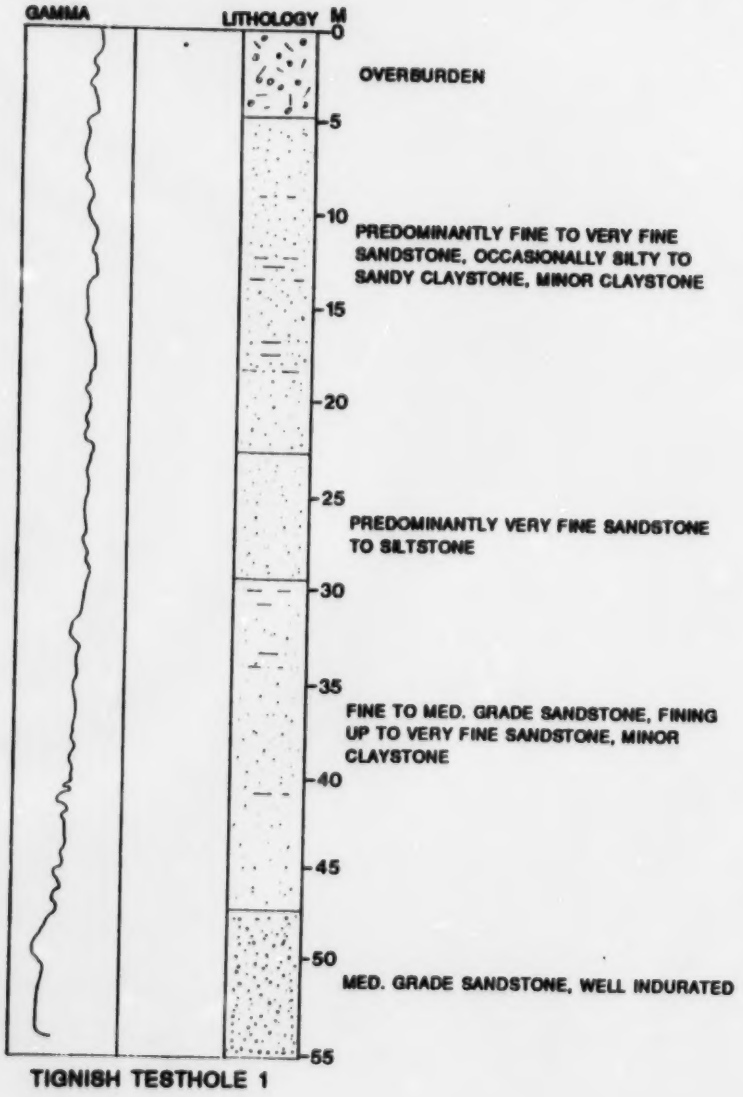
4.2.3 Pump Testing

Following completion of the wells a step drawdown test was conducted to asses well performance and select an appropriate pumping rate for a subsequent constant rate test. This constant rate test was than conducted on one of the two wells to determine the aquifer characteristics in the area. The second well was used as an observation well during the constant rate test.

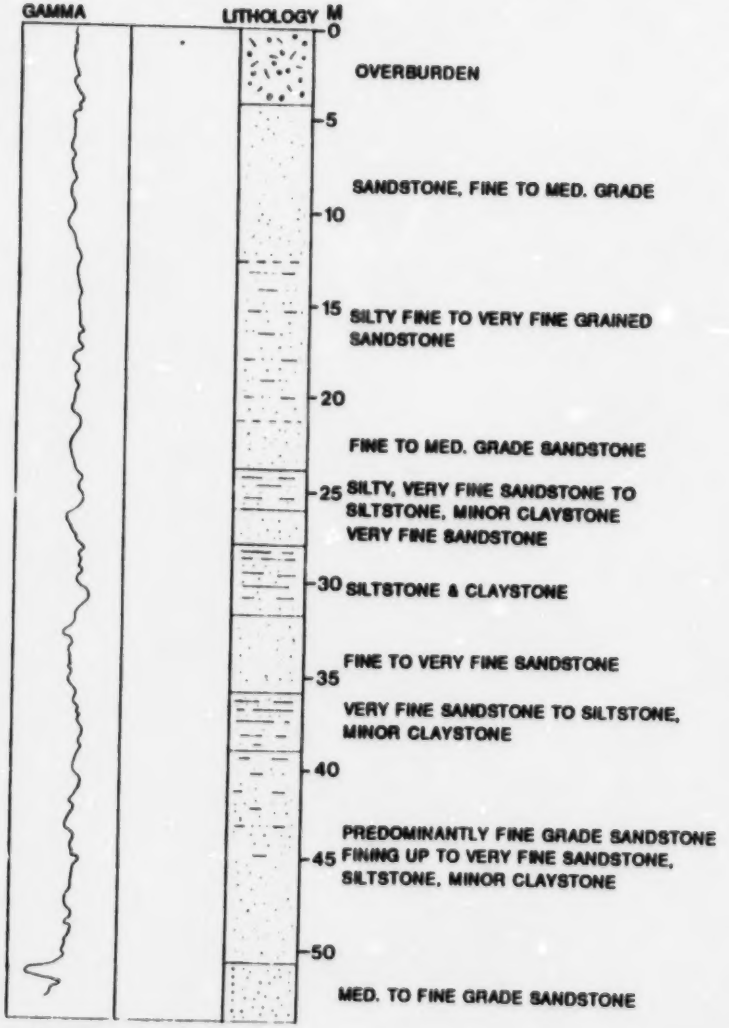
Step Drawdown Tests:

Following completion of the two test wells, step drawdown tests were conducted to give n initial indication of well yield and to select an appropriate pumping rate for a subsequent 48 hour constant rate test on one of the two wells. The initial plans called for tests consisting of three steps of 1/2 hour duration each. Unfortunately because of pump capacity, and problems of throttling the pump down to lower rates, only two steps were conducted in each test. Table 1 summarizes the results of these tests, indicating the pumping rate for each step, the amount of drawdown, and the specific capacity.

Figure 2



TIGNISH TESTHOLE 1



TIGNISH TESTHOLE 2

Specific capacity is a measure of the relationship of pumping rate to drawdown. Normally it would be expected that as the pumping rate increases, the specific capacity would decline because of the increase in total head losses associated with turbulent flow (commonly called well losses) that may accompany higher flow rates. In this case however, the specific capacity in each well has in fact increased with increasing pumping rates, which suggested that the wells were containing to develop during the tests.

Table 1 STEP DRAWDOWN TEST DATA, TIG-1 and TIG-2

Well	Pumping Rate (L/sec.)	Drawdown (m)	Specific Capacity (L/sec/m)
TIG-1	3.9	2.9	1.4
TIG-1	5.3	3.3	1.6
TIG-2	3.9	3.1	1.3
TIG-2	6.1	3.2	1.9

Based on these results it was concluded that either well could be pumped at a rate considerably in excess of the capacity of the pump used during the test, however it is not possible to predict what the maximum rate the wells could sustain would be with this data. Since the initial indications were that the flow rates obtained from this testing were well in excess of the probable needs of the community, testing at higher rates was not pursued at that time.

Constant Rate Test:

To gain further information about the aquifer characteristics of the area, a constant rate test was performed, allowing calculation of the aquifer Transmissibility and storativity. Based on the step drawdown data, test well TIG-1 was selected as the pumping well for a 48 hour constant rate test at a rate of 5.3 L/sec., while test well TIG-2 was used as an observation well. Following the test, recovery measurements were made for a period of 3 hours. The maximum drawdown observed in the pumping well was 4.2 m while only 0.2 m of drawdown was observed in the observation well. This pump test data was analyzed by both Theis curve fitting techniques and Jacob modified non - equilibrium methods utilizing pumping and observation well data. the results of these analyses are presented in Table 2 .

It is evident that there is a vast difference (nearly an order of magnitude) in the values obtained for transmissibility from the observation well data and the pumping well data. It is quite usual for values derived from analysis of observation well data are somewhat higher than those calculated from pumping well data because the observed drawdown (head loss) in the pumping well would be expected to include some well losses which would not be evident in the observation well. For these reasons, observation well data is usually preferred However in this case, the value calculated from the pumping well recovery data, which should also be unaffected by well losses, should be similar to values obtained form the observation well data. In this case the recovery data suggests a transmissibility in relatively good agreement with the pumping well data. It is suggested that a transmissibility value in the range of 100 m^2/day is a reasonable estimate.

Table 2 Calculated Aquifer Parameters

Type of Analysis:	Transmissibility (m^2/day)	Storativity
Observation well data:		
Theis method	830	9.7x10-4
Jacob	934	6.8x10-4
Pumping Well Data:		
Jacob	103	-------
Recovery Data	95	-

4.3 Groundwater Flow Regime

The relatively dense distribution of domestic water wells, combined with the considerable volume of data collected during investigation of Dinoseb contamination in the community, makes it possible to develop a reasonable picture of Groundwater flow conditions in the central portion of Tignish. Outside this area, the groundwater flow regime can be described only in general terms. Figure 3 shows the general configuration of the groundwater flow system for all but the outermost portions of the community, where data are insufficient to outline hydrogeological conditions with any degree of confidence. The pattern of groundwater flow is somewhat radial, although generally from north to south from the high point of land near the northern extent of town. This high point is near the apex of several small sub watersheds which drain to the south and south west towards the Tignish River and to the north east towards Judes Point. The overall hydraulic gradient appears to be in the range of 1.5% , being fairly shallow to the north , and further to the south near the Tignish River. The data suggest

Figure 3

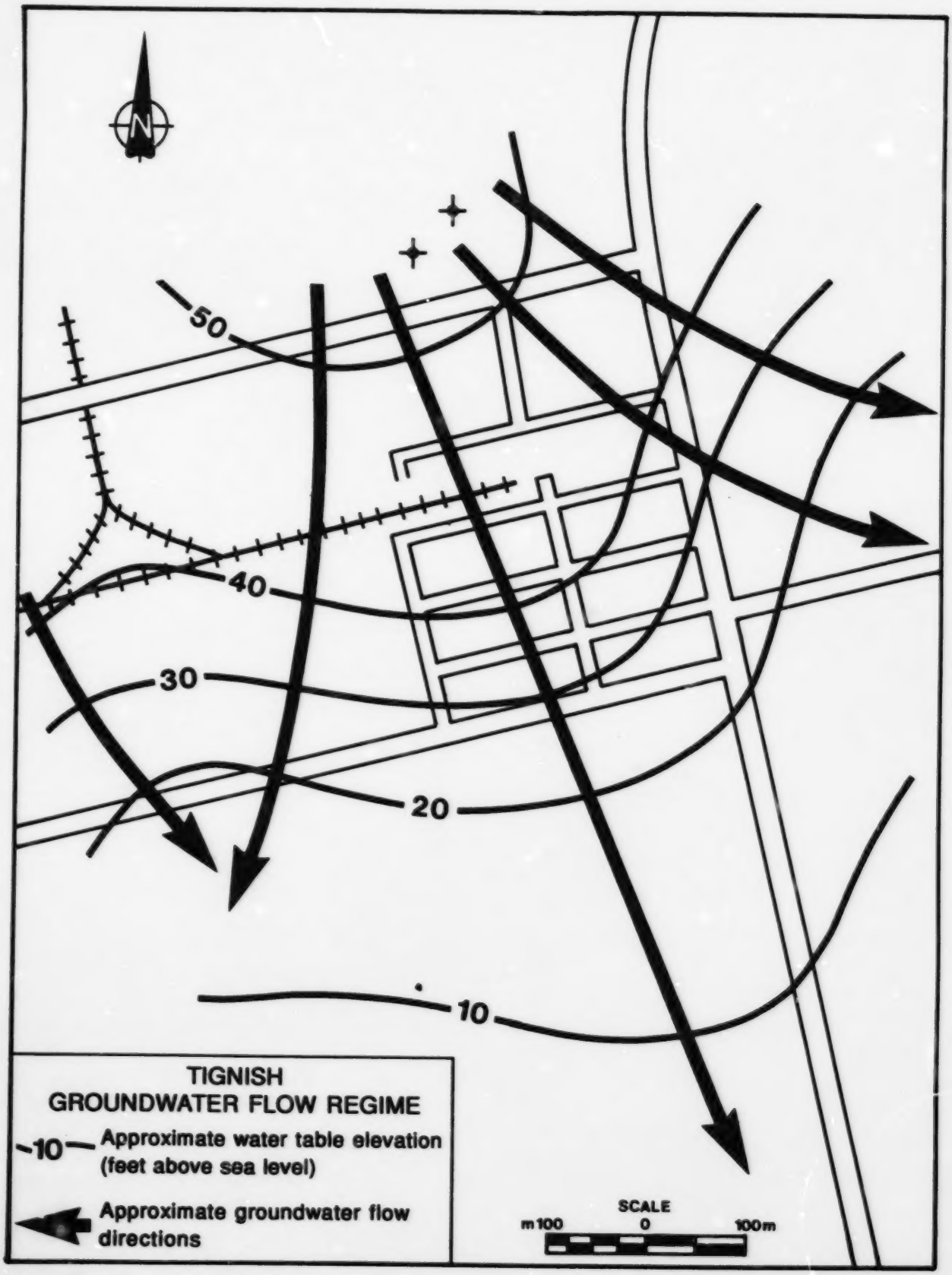
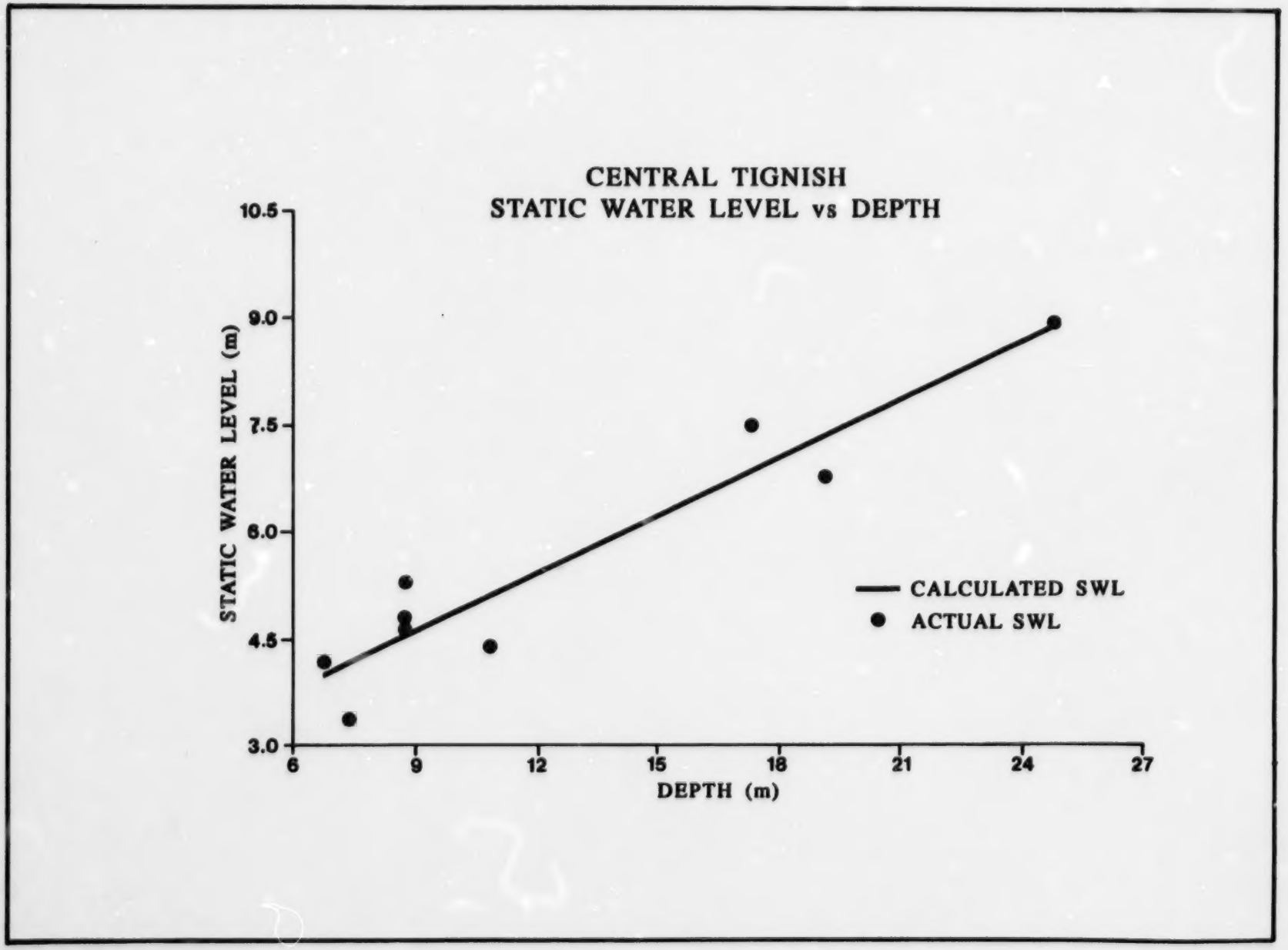

N
50
40
30
20
10
TIGNISH
GROUNDWATER FLOW REGIME
10
Approximate water table elevation
(feet above sea level)
Approximate groundwater flow
directions
SCALE
m 100
0
100 m

Figure 4


CENTRAL TIGNISH
STATIC WATER LEVEL vs DEPTH
STATIC WATER LEVEL (m)
10.5
9.0
7.5
6.0
4.5
3.0
6
9
12
15
18
21
24
27
DEPTH (m)
CALCULATED SWL
ACTUAL SWL

that in the central portion of the community the gradient is considerably steeper, possibly as high as as 3.8%. Most of the area appears to be a recharge area, and Figure 4 shows the correlation between well depth and static water level for nine wells in the central portion of the community, with static water level increasing with well depth as would be expected. The data suggests the presence, at least at shallow levels, of fairly strong vertical gradients in the range of 0.25 m/m.

5. Groundwater Quality

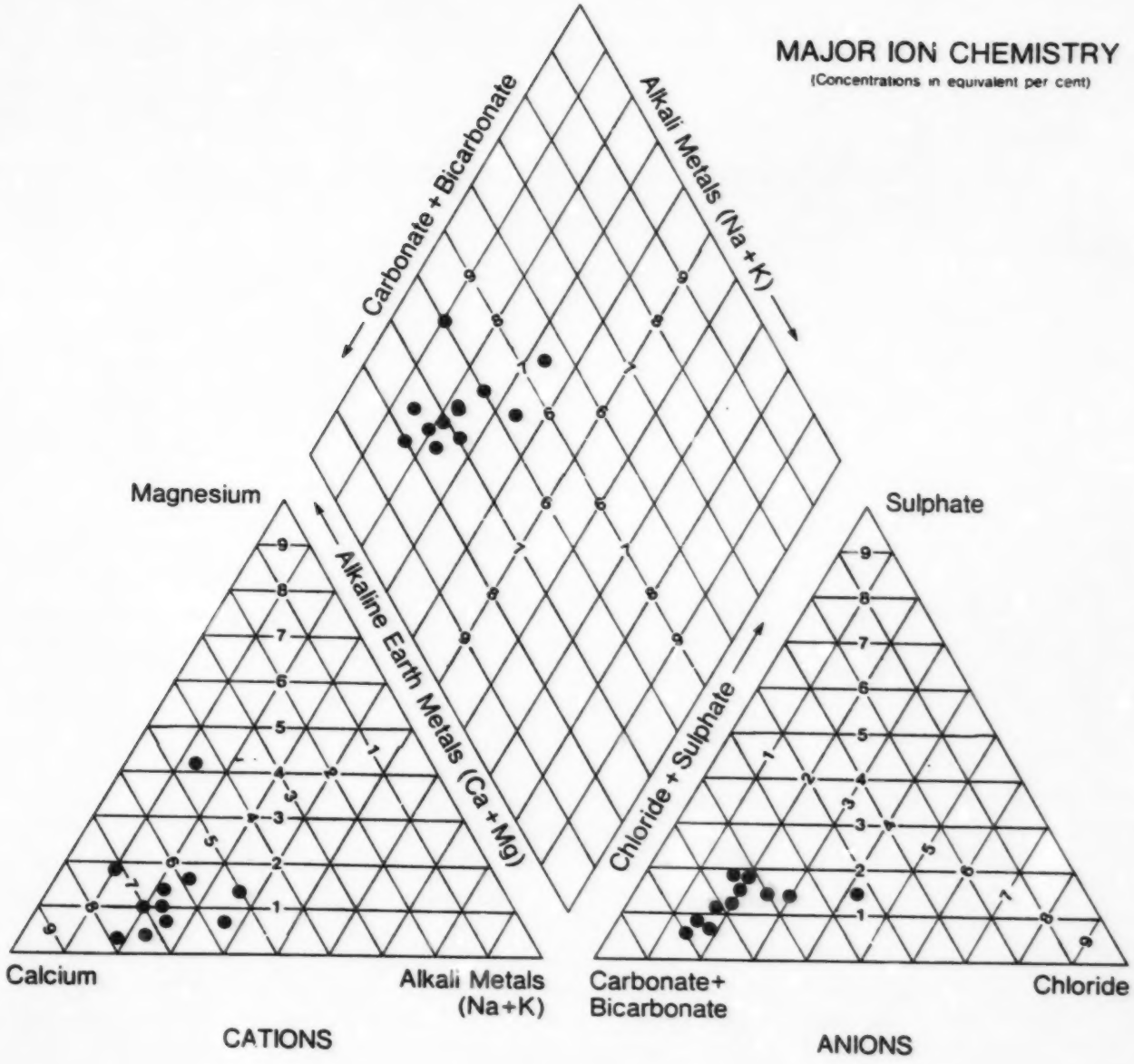
5.1 Baseline groundwater Quality

An assessment of Baseline groundwater quality in the Tignish area was made by reviewing departmental files for water analysis as well as results from groundwater samples collected suring this investigation. The results show natural groundwater quality to be very good , with the water typically being moderately hard to hard, neutral to slightly alkaline in pH and with the same calcium bicarbonate chemistry typically found throughout the western part of Prince Edward Island. The relative proportion of the major ionic species are shown for a selection of samples on Figure 5.

Localized occurrences of elevated iron and manganese concentrations appear to be the only natural water quality problems in the area with approximately 14% of analyses total iron concentrations and 18% of analyses showing levels of manganese at or above the aesthetic objective levels of 0.3 mg/L and 0.05 mg/L for iron and manganese outlined in the Guidelines to Canadian Drinking Water Quality (Health and Welfare Canada, 1989). These occurrences of elevated iron and manganese concentrations do not appear to show any systematic distribution throughout the community, and do not pose a health threat.

Nitrate concentrations are generally low, with over 50% of results indicating NO_3-N concentrations less than 2 mg/L and over 80% of results below 4 mg/L. These values are comparable with nitrate concentrations found in relatively pristine areas. A few analyses show NO_3-N concentrations at or slightly above the maximum acceptable concentration (10 mg/L) as set out in the Guidelines to Canadian Drinking Water Quality. There is virtually no agricultural activity within the community itself, and the area is serviced by central sewer thus septic tank effluent is not to blame, however these occurrences may reflect instances of poor well construction and or localized leaks in sewer lines.

Figure 5


MAJOR ION CHEMISTRY
(Concentrations in equivalent per cent)
Carbonate + Bicarbonate
Alkali Metals (Na + K)
Magnesium
Alkaline Earth Metals (Ca + Mg)
Sulphate
Chloride + Sulphate
Calcium
Alkali Metals (Na+K)
Carbonate+ Bicarbonate
Chloride
CATIONS
ANIONS

5.2 History of Water Quality Problems

In spite of the naturally good water quality in the area, Tignish has been the scene of several serious groundwater contamination events, and water quality concerns generally far outweigh quantity concerns in the area.

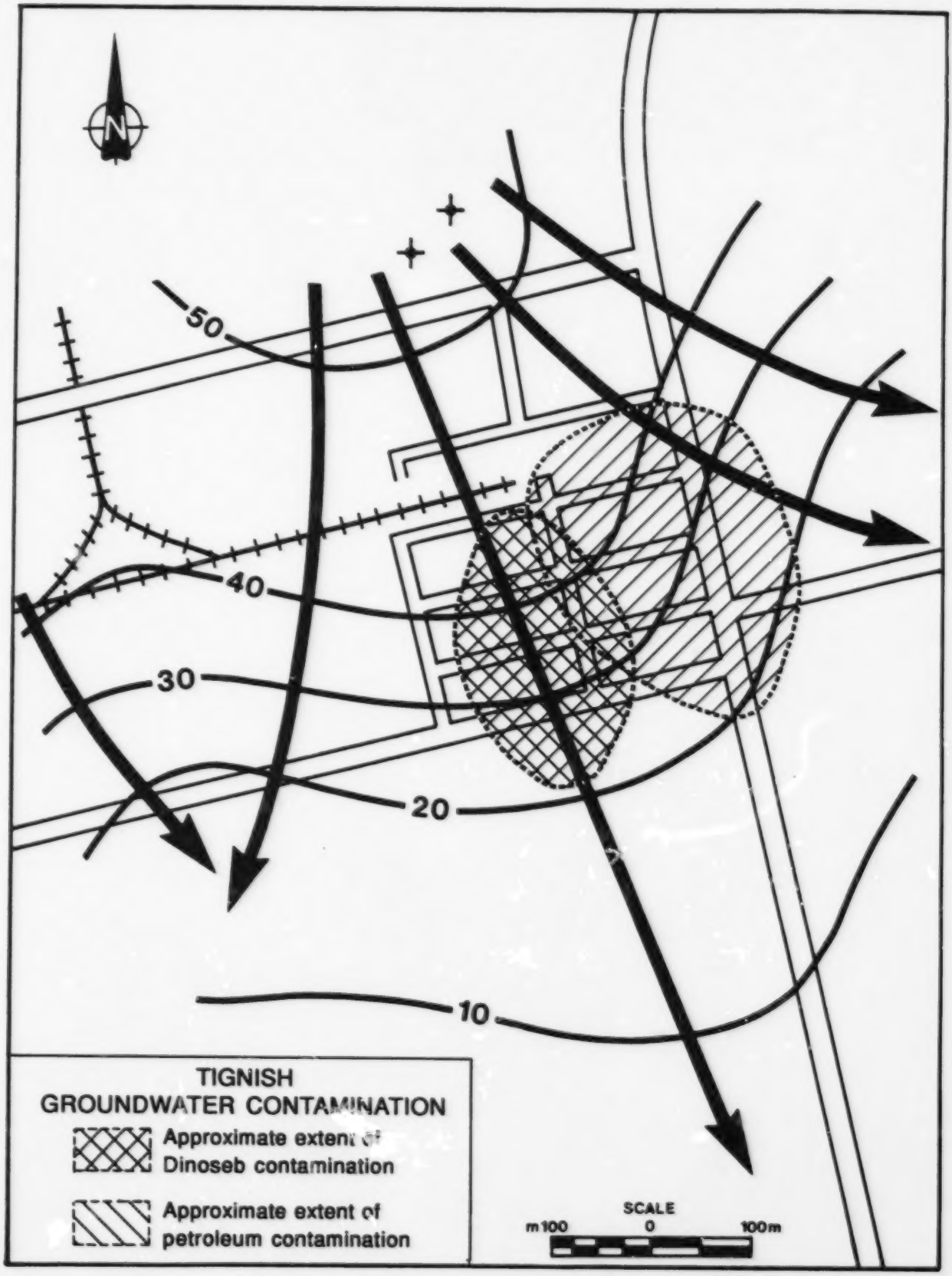
In the mid 1960'approximately 10,000 litres of fuel oil spilled from bulk storage tanks located just to the north of the centre of town. In the spring of 1978, 13,000 litres of gasoline were lost from underground storage tanks at the Coop service station in the same area of town. In addition to these major spills, at least one small fuel oil spill has occurred in the same general area.

The most recent and possibly most serious incident occur in the community involved the contamination of the aquifer in the central portion of the community by an unknown quantity of the pesticide Dinoseb. Investigations by the P.E.I. Department of the Environment have delineated the extent of contamination as well as the probable source area for the spill although the exact source, quantity and timing of the event remains a mystery.

Dinoseb contaminated water was first discovered in June of 1989, during a routine investigation of a complaint of discoloured (yellowish) water from a well in the central part of the community. When standard chemical analysis failed to shed light on the cause of the problem, the water was analyzed for the Dinoseb, a herbicide not frequently used now but formerly applied extensively, and notable for its strong yellow colour. The results of this analysis indicated a concentration of Dinoseb of 690 parts per billion (the guidance value for Dinoseb in drinking water, recommended by Health and Welfare Canada is 10 parts per billion (ppb). These findings triggered a more detailed investigation including the excavation of 9 test pits and 7 test wells in an effort to pinpoint the source of the dinoseb and in concert with a survey of domestic wells, delineate the extent of the contaminant plume.

As a result of this survey it was found that wells for nine households had concentrations greater than the 10 ppb guidance value, and a further 12 households had concentrations between 1 ppb and 10 ppb. The highest concentrations found during the investigation were all from the well in which the Dinoseb was first detected and reached a peak of 920 ppb in October before the well was abandoned and grouted. A total of six wells showed concentrations of over 100 ppb at least once during the sampling program. The extent of the contaminant plume, as it was first delineated in 1989, and the direction of groundwater flow, is shown on Figure 6. Also shown on Figure 6 is the approximate extent of petroleum contamination in the area as well as groundwater flow directions. Subsequent monitoring of test wells and domestic wells has shown little change in the extent of the contaminant plume, although samples collected in January of 1991 indicate the presence of Dinoseb at low concentrations (0.3 ppb) from a well located approximately 100 m further south along the direction of groundwater flow, than previously detected.

Figure 6


N
50
40
30
20
10
TIGNISH
GROUNDWATER CONTAMINATION
Approximate extent of
Dinoseb contamination
Approximate extent of
petroleum contamination
SCALE
m100
0
100m

In spite of the extensive efforts to identify the source of the contamination, investigations so far have only succeded in narrowing the location of the spill to an area of a few hundred square metres on a vacant lot between Spring Lane and Main Street. At this point it appears unlikely that more will be learned about the source, although the P.E.I. Department of the Environment continue to monitor selected wells in the area on a regular basis. The area of the community affected, as well as areas affected by petroleum contamination are now serviced by a central water system.

5.3 Potential Threats to Groundwater Quality

Natural groundwater quality in Tignish is generally good but man-made influences have seriously impaired groundwater quality in significant portions of the community. While the areas affected most by groundwater contamination are now serviced by central water, a substantial area can expect to rely on good quality groundwater form on-site (private) water supplies, if proper care is taken in the management of the resource. This vigilance should extend to areas already contaminated, as groundwater is not static - what may be a problem in one location now may become someone else's problem in the future. Probably the most effective tool in the management of any resource is a recognition of the factors that threaten it.

Probably the most common threat to groundwater quality on Prince Edward Island is contamination by petroleum products from leaking underground storage tanks. The community of Tignish has already been the site of several of these incidents, and it is only realistic to expect that other spills could occur in the future. Therefore groundwater in the immediate vicinity around service stations or other locations where significant quantities of petroleum products are stored is probably at some risk of contamination. It is worth mentioning also that while large underground petroleum storage tanks perhaps pose a greater risk to groundwater resources when taken individually, because of their numbers, domestic home heating oil tanks have statistically account for a significant portion of contamination events.

The community of Tignish is serviced by a central sewer system, and problems with bacterial contamination of wells appears not to be a particular concern. Nonetheless, overburden in Tignish is relatively permeable and locally fairly thin, and on-site water supplies, particularly older, shallow wells are expected to be vulnerable to bacterial contamination.

Finally, although posing only an indirect threat to water quality in the community, the very source of water itself (individual wells) may be as much a reason for concern as many of the more direct and obvious hazards affecting water quality. Each well (particularly poorly constructed wells or wells with shallow casing) represents a discreet pathway for water, and any potential contaminants it may carry, from the near surface environment to portions of the aquifer from which water supplies are obtained. While the impact of each well individually,

may be small, cumulatively the influence of such a density of wells will inevitably alter conditions in the subsurface environment including groundwater quality. Of particularly concern is the potential for one contaminated well to spread contaminants to other wells in the area. For these reasons it is particularly important that wells which are no longer in use due to contamination are properly abandoned. In addition it is important to be vigilant over such issues of proper construction of new wells for the same reasons.

6 Planning Considerations

6.1 Availability of Groundwater

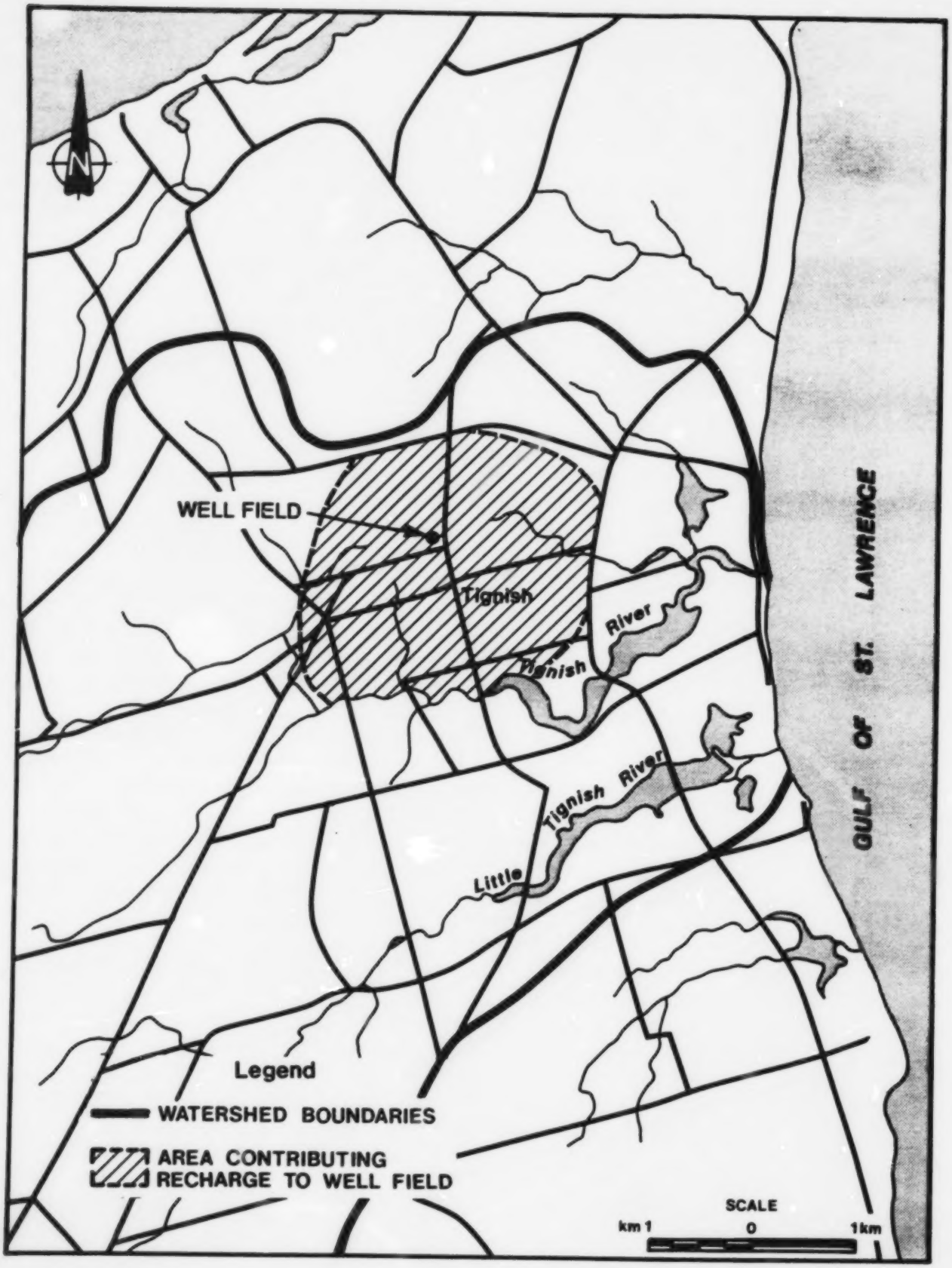
A review of the available hydrogeological data indicates that well yields, while generally low compared with some areas of the Island, are sufficient to meet most of the requirements of the community. Highest yields are reported from the north eastern part of Tignish, as demonstrated by test wells constructed the vicinity of St. Judes Church, and wells servicing the Senior Citizens Home and the Elementary School. Further south the development of higher capacity wells has proved more difficult, with the notable exception of the well at the old Fire Hall (now the community office) on Phillips Street, and attempts to develop a high capacity well at the new Fire Hall further south on Church Street have not met with much success. Securing adequate volumes of water for domestic requirements is not a problem in any area of Tignish.

With a population of just under 1000, Tignish's water requirements are fairly modest, and based on a consumption of 0.27 m^3 per day per person, are likely to be in the range of 270 m^3/day (3.2 L/sec.). Peak flow requirements may be about three times this amount at a rate of 9.5 L/sec. The two test wells constructed as part of this program currently supply water to the central system which services the area in the community where groundwater has been contaminated by Dinoseb and petroleum products.

To meet the needs of the system as it is designed it was anticipated that an average flow of approximately 200 m^3/day would be required. Pump testing of these two wells indicate that they are capable of producing in the range of 950 m^3/day (11.4 L/sec.), considerably in excess of the current average daily flow requirements for the entire community and comfortably in excess of the expected peak flow requirements. In addition this yield is well balanced between the two wells so that average requirements could easily be met with only one well operating in the event of mechanical failure.

Sufficient capacity remains for considerable expansion of the distribution system, but with no provision for storage, the demand at peak flow conditions could require the construction of an additional well if substantial expansions were anticipated. At the current rate of growth the existing supply should be sufficient for some years to come.

Figure 7


N
WELL FIELD
Tignish River
Tignish River
Tignish River
Little
GULF OF ST. LAWRENCE
Legend
WATERSHED BOUNDARIES
AREA CONTRIBUTING
RECHARGE TO WELL FIELD
SCALE
km 1
0
1km

When considering the extraction of any significant quantity of groundwater, it is important to consider the impact of groundwater withdrawals on other water users, including potential effects pumping may have on surface water flows in the area. The concern over impacts on surface water flows stems from the fact that a very significant portion of stream flow in P.E.I. is from baseflow (groundwater discharge into streams). A significant reduction in the amount of groundwater available could seriously reduce stream flows in the dryer months of the year.

In the case of Tignish, the volume of water which would be pumped is so low that no such impacts would be anticipated. Pump test data would suggest that interference effects between any adjacent wells should be minimal if detectable. In terms of impacts on surface water resources, the well filed is located near the apex of three small sub watershed boundaries, and the effects of groundwater withdrawals, if any would be presumably be distributed between all three subwatersheds. While small, these subwatersheds have a combined area in the vicinity of 6 km^2. (see Figure 7). Assuming that annual precipitation is in the range of 1100 mm per year, and that annual recharge averages 35% of precipitation, then the expected groundwater withdrawals necessary to meet the requirements of the entire community would represent less only about 8% the available recharge to these streams.

6.2 Groundwater Protection

The importance of groundwater resources to the health and welfare of Island communities is well recognized, probably nowhere more than in Tignish. To a lesser extent the importance of implementing sound, far sighted strategies aimed at protecting this valuable resource is also appreciated. The following discussion attempts to provide some focus to this issue, by presenting some possible approaches to the development of a comprehensive groundwater protection strategy. The issue of groundwater protection can be separated into two components: specific recommendations for the protection of central water supply wells and the general considerations pertinent to the establishment and operation of on site water supplies and the protection and preservation of the resource in general. The more important aspects of this latter aspect have been addressed in the previous section of this report under "Potential Threats to Groundwater Quality"

Well Field Protection

Unlike the processes that lead to the contamination of surface water bodies, the degradation of groundwater resources is not subject to direct observation, and consequently is more difficult to predict and correct. Once contaminants have been introduced into a groundwater system, their migration and fate is governed by a complex series of reactions and processes which depend on a number of parameters which may be only poorly documented. Consequently the prediction of the consequences of the introduction of contaminants into a groundwater reservoir in the vicinity of wells supplying a water supply system requires a number of approximations and assumptions of varying validity.

A number of approaches have been developed to provide varying degrees of protection to wells supplying central water systems. In general, the object of these strategies is to designate an area around the well or well field, for which activities which have the potential to have an adverse effect on the water supply are restricted or prohibited. Frequently a number of concentric zones around a well or well field are defined, with progressively less stringent land use restrictions for each zone with increasing distance from the well or well field.

The major parameters in developing groundwater protection strategies for municipal water wells are legal, socio-economic, and hydrogeological (Alan Gregory, 1988). In this report, suggested protective strategies are based primarily on hydrogeological parameters. It is recognized that the modification of these strategies in the light of socio-economic factors may be necessary, however the principles behind them do provide a defensible, technical basis for decision making regarding the protection of groundwater resources.

There are a wide variety of techniques which have been employed to define the extent of various groundwater protection zones. Three types of zones considered in this report are defined below.

Radius of Influence - The areal extent of the] cone shaped depression in the water table, or in the piezometric surface, resulting from the pumping of water from a well or well field. Within this area it is recommended that no residential, commercial, or industrial development take place, and that restrictions be placed on agricultural activities. The area would however be suitable for the development of some types of recreational activities.

Delay Time Zone - An area enclosed by a line representing the distance from which potential contaminants are expected to migrate towards a well or well field in a given period of time (60 days in this case) under pumping conditions. Within this area, it is recommended that on-site sewage disposal (septic systems)be prohibited, and the storage, or handling of hazardous materials including petroleum products be prohibited. In addition, any other development proposals or activities should be subjected to an environmental impact assessment, at least in regard to their possible impact on the integrity of the water supply system.

Catchment Area - A zone outlining the area in which groundwater is expected to flow to the well or well field, both under pumping conditions and under the existing natural hydrogeological flow regime. Within these areas, major development proposals or proposed land use changes should first be subjected to an environmental impact assessment.

These methods described above have the appeal that they can be based on the actual characteristics of the aquifer, and thus can be justified to some extent on their scientific foundations. It should be noted at the outset however, that rarely are aquifer characteristics sufficiently well known that the suggested protection zones provide an absolute guarantee of protection. None-

theless, these approaches can help in developing rational water management policies, which can be refined and improved as additional information becomes available or insight into actual field conditions accumulates.

Each of the approaches has its strengths and weakness, and it is perhaps advisable to develop well field protection strategies which incorporate the most appropriate aspects of each approach. The following considerations may form the basis for such an approach, and are based on the current demands placed on the wells supplying the central water system newly established in the community. The extent of these zones should be reviewed if at some time in the future greater demands for water are anticipated. The extent of of these zones is illustrated on Figure 8.

Radius of Influence :

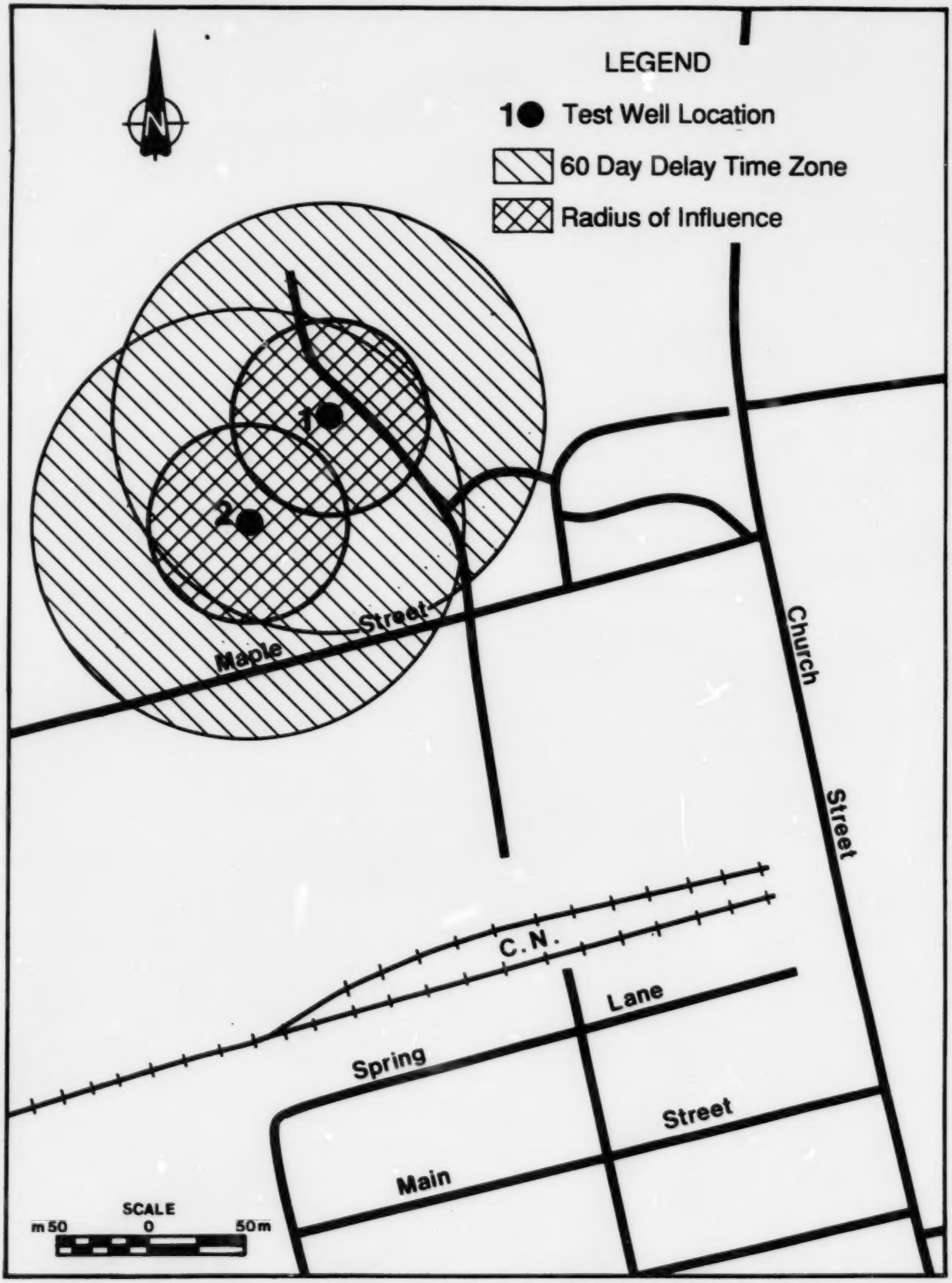
The inner most protective zone designated here is the "radius of influence" of the wells, and represents the area in which the effects of pumping have a direct effect on the groundwater flow regime and in which the well is probably most vulnerable to contamination. There are a number of approaches by which the extent of this zone can be delineated, and theoretically this zone could be of infinite extent. The approach taken here is to define the zone as the area in which the hydraulic gradient induced as a result of pumping is greater than or equal to the existing natural hydraulic gradient. Based on the available pump test data and the expected average pumping rate for these wells, it is estimated that this zone will have a radius of approximately 50 m. A doubling of the pumping rate from these wells is expected to result in a radius of influence of approximately 100 m.

Delay Time Zone:

The rate at which a contaminant can travel towards a well is a function of a number of factors including the nature of the aquifer materials, the natural hydraulic gradient, and the hydraulic gradient induced by pumping. As might be expected, the higher the pumping rate, the more rapidly a contaminant will travel towards a well, and the larger the radius of the delay time zone will be.

A convenient starting point would be to identify a 60 day delay time zone. A zone of this size should provide protection against most pathogenic organisms (60 days is the maximum time most pathogenic organisms are believed to survive in groundwater).This zone also provides sufficient lead time that an alternate well location could be adopted if a particular serious incidents of contamination threatened the water supply. Thus if for instance a spill of hazardous material occurred at the edge of this zone, the community would have approximately 60 days in which to take whatever remedial measures were possible, before the contaminant would be expected to reach the well. For the wells under consideration here, it is estimated that the 60 day delay time zone has a radius of 100 m at the current pumping rate. This radius would increase to approximately 150 m if the average rate of groundwater extraction were doubled.

Figure 8


LEGEND
1 Test Well Location
60 Day Delay Time Zone
Radius of Influence
N
1
2
Maple
Street
Church
Street
C.N.
Lane
Spring
Street
Main
SCALE
m 50
0
50 m

Catchment Area:

Because the well field under consideration is at or near the local watershed divide, and the natural direction of groundwater flow (without any influence of pumping) would be expected to be away from the well field, the concept of a catchment area is not particularly relevant in this case. The area contributing to groundwater flow towards the wells would be expected to be adequately defined by the radius of influence of the wells or the 60 day delay time zone. With these considerations in mind, no catchment area has been defined for the well field.

7. Conclusions and Recommendations

Tignish has more than an adequate groundwater resource, but as past events have shown, the availability of good quality groundwater can not be taken for granted. Well yields, while adequate to meet domestic requirements, are not such that the development of high capacity wells can be guaranteed in all parts of the community. In addition groundwater quality in a large part of the community has been impaired to some extent by man-made influences.

Generally, areas unaffected by groundwater contamination should expect to continue to enjoy reliable sources of water form existing on-site water supplies, although the economics of central water supply may be attractive to residents not currently serviced by the central water system. The wells supplying the central water system have ample capacity to meet current system needs and have enough remaining capacity to support a considerable amount of expansion. In order to protect the investment the community has in this water supply, appropriate well field protection measures should be adopted.

Locally some areas hydrogeologically "down stream" from contaminated groundwater may be vulnerable to contamination depending on the fate of present contaminant plumes, and continued monitoring of the extent of contamination will be important. A heightened awareness of water quality issues including a recognition of the importance of proper well construction and abandonment, and the safe handling and storage of hazardous materials including petroleum products will be important components in the successful management of this resource.

References:

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Gregory, A., 1988: Inventory and review of New Brunswick municipal groundwater supply areas, prepared for Environment Canada, Consevation and Protection, Atlantic Region

Health and Welfare Canada, 1989: Guidelines for Canadian Drinking Water Quality, Dept. of Supply and Services, Ottawa

Van de Poll, H.W., 1981 Geology of Prince Edward Island; Prince Edward Island Department of Tourism, Industry and Energy

APPENDIX I

WATER WELL DATA

APPENDIX I
TIGNISH

WATER WELL DATA

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Ivan Ellsworth	710621	419080	5197720	60	50	12	24			0-20 Clay 20-60 Limestone and sandstone	28 31 55 58
Tom Harper	720919	419099	5200893	60	70	20	21	8	15	0-7 Clay 7-60 Sandstone	40 43 55 58
Neil LeClair	780615	419103	5200782	99	100	25	23	8	10	0-12 Sand till 12-99 Sandstone, some claystone	28 31 59 62
Sidney MacCallum	710610	419300	5197891	64	50	30	21	8	15	0-6 Clay 6-64 Sandstone	50 53 64 66
Joseph McPhee	840321	419300	5198300	66	100	20	45	10	5	0-15 Sand and claystone 15-66 Sandstone and claystone	27 28 40 43 55 58
Angus Handrahan	801028	419400	5198800	58	50	25	27	5	5	0-3 Sand and clay 3-58 Sandstone and claystone	36 39
Sylvie Arsenault	771219	419450	5198800	40	40	10	30	8	8	0-8 Claystone 8-40 Sandstone, some claystone	35 38 60 61
Ann Doucette	801010	419800	5199400	61	50	28	32	5	5	0-5 Sand and clay 5-61 Sandstone, some claystone	25 40
Frank Handrahan	721219	420000	5199493	53	50	24	17	8	15	0-9 Clay till 9-53 Sandstone	25 27 38 41 59 60
Regis Harper	781127	420000	5199600	60	50	38	25	5	8	0-7 Clay and sand 7-60 Sandstone, some claystone	
Michael Christopher	710506	420080	5199510	53	50	15	18	8		0-8 Clay 8-53 Limestone, some sandstone	35 40 60 70
John Perry	790917	420100	5199200	75	50	23	31	8	10	0-9 Clay till 9-75 Sandstone, some claystone	29 32 48 51
Kenneth MacRay	700623	420100	5199600	54	50	13	24	8	15	0-17 Sand 17-54 Sandstone	55 58 73 75
Dave Klinch	851130	420100	5199600	75	50	30	31			0-2 Clay 2-75 Sandstone and claystone	62 65 72 75
Olive's Groceries	810811	420200	5199800	75	50	20	43	5	5	0-2 Till 2-75 Sandstone, some claystone	33 36 45 48 66 68
ATO Property Ltd.	831128	420300	5199750	68	50	18	33			0-16 Claystone 16-68 Sandstone, some claystone	45 48 62 64
Perry's Construction	821222	420340	5200200	64	50	20	35	5	5	0-34 Claystone 34-64 Sandstone, some claystone	

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)
ATO Property Ltd.	831128	420350	5199750	65	50	22	34			0-12 Claystone 12-65 Sandstone, some claystone	44 47 64 65
Perry's Construction	821221	420350	5200200	65	50	22	35	5	5	0-34 Claystone 34-65 Sandstone	46 49 63 65
Perry's Construction	821218	420380	5200200	72	50	20	32	5	5	0-20 Claystone 20-72 Sandstone, some claystone	42 45 68 71
ATO Property Ltd.	831124	420400	5199750	65	50	25	34			0-15 Claystone 15-65 Sandstone, some claystone	43 47 64 65
ATO Property Ltd.	831116	420400	5199750	70	50	32	35			0-3 Clay 3-70 Sandstone and claystone	45 48 69 70
Floyd Gaudette	800710	420400	5200100	60		21	29	5	5	0-26 Sand and sandstone 26-60 Sandstone, some claystone	47 50 59 60
Perry's Construction	790103	420400	5200200	60	50	50	30	5	5	0-3 Clay and sand 3-60 Sandstone, some claystone	42 46 54 57
Perry's Construction	781230	420400	5200200	60	50	50	30	5		0-4 Clay and sand 4-60 Sandstone, some claystone	34 37 41 44 57 60
Perry's Construction	821216	420400	5200200	65	50	20	34	5	5	0-15 Claystone 15-65 Sandstone, some claystone	41 44 62 65
Perry's Construction	790105	420500	5200200	60	50	52	30	5	5	0-4 Clay and sand 4-60 Sandstone, some claystone	45 48 58 60
Perry's Construction	790104	420500	5200200	60	50	52	30	5	5	0-4 Clay and sand 4-60 Sandstone, some claystone	42 45 59 60
Perry's Construction	781228	420500	5200200	60	50	50	30	5	5	0-5 Clay and sand 5-60 Sandstone, some claystone	38 41 54 57
Perry's Construction	781229	420500	5200200	60	50	50	30	5	5	0-6 Clay and sand 6-60 Sandstone, some claystone	40 43 58 60
Nelson Gaudet	850408	420600	5200100	64	50	20	40			0-2 Clay 2-64 Sandstone and claystone	50 53 62 64
Perry's Construction	821115	420600	5200200	60	50	20	34	5	5	0-1 Clay 1-60 Sandstone, some claystone	44 47 58 60
Perry's Construction	821216	420600	5200200	66	50	20	36	5	5	0-34 Claystone 34-66 Sandstone	45 48 62 65
William Handrahan	780804	420700	5199800	65	50	15	28	6	12	0-5 Clay till 5-65 Sandstone	33 36 54 60

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Clifford Bernard	711111	420751	5199882	52	-35	20	39			0-20 Clay 20-52 Sandstone, some claystone	
Henry J. Gaudet	770711	420800	5199800	58	50	12	22	8	10	0-12 Clay till 12-58 Sandstone, some claystone	40 50
William Handrahan	770708	420800	5199800	68	25	18	25	8	10	0-12 Clay till 12-68 Sandstone, some claystone	25 30 60 65
Everett Richard	781002	420800	5199800	50	25	35	25	5	5	0-5 Clay and sand till 5-50 Sandstone and claystone	33 39 48 50
Frank Hogan	831029	420800	5199800	55	50	22	33			0-10 Sand and claystone 10-55 Sandstone and claystone	43 48 54 55
Aubin Bernard	851229	420800	5199800	64	50	28	30			0-2 Clay 2-64 Sandstone and claystone	43 46 63 64
Percy Hennessey	710801	420800	5200180	60	25	20	20	8		0-10 Sand 10-60 Sandstone, some claystone	
Elmer Arsenault	820810	420800	5200300	60	50	22	33	5	5	0-2 Clay 2-60 Sandstone and claystone	40 43 58 60
Gerald Pickle	780124	420850	5199850	65	25	20	42	7	7	0-6 Till 6-65 Sandstone and claystone	55 57
Henry Buote	720519	420899	5201394	67	75	15	24	8	15	0-20 Sand 20-67 Sandstone	33 36 61 64
Earl MacRae	840813	420900	5198700	58	25	20	35	10	5	0-2 Clay 2-58 Sandstone and claystone	45 48
Joseph Perry	791030	420900	5199800	66	50	45	52	5	10	0-3 Clay 3-66 Sandstone and claystone	64 66
Perry's Construction	770131	420900	5200000	70	50	19	34	8	10	0-12 Sand till 12-70 Sandstone, some claystone	55 65
Elizabeth Cran	851204	420900	5200700	50	50	20	30			0-2 Clay 2-50 Sandstone and claystone	40 43 48 50
Arthur Finnissy	720718	420901	5200093	60	50	14	24	8	15	0-17 Sand 17-60 Sandstone	30 33 55 58
Michael Callahan	760709	421000	5200000	20		15	14			0-14 Sand and clay till 14-20 Sandstone	14 15 19 20
Don Landry	760814	421000	5200000	22		18	8			0-8 Sand till 8-22 Sandstone	8 12 21 22

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)					
Tignish Fire Dept.	830106	421050	5199800	194	40	27	58	75	90	0-8 Till	77	80	125	130	180	182
										8-194 Sandstone and claystone						
Fitzgerald & Snow	721027	421099	5199892	132	30	32	85	8	15	0-5 Clay till	90	93	128	131		
										5-132 Sandstone, some claystone						
Lena Fitzgerald	800418	421100	5199000	56	50	18	41	5	5	0-3 Clay	49	51				
										3-56 Sandstone, some claystone						
Boyd Bernard	840820	421100	5199100	50	50	20	40	10	10	0-2 Clay	45	48				
										2-50 Sandstone and claystone						
Tignish Rink	770621	421100	5199700	85	50	18	30	8	10	0-12 Sand till	35	40	75	80		
										12-85 Sandstone and claystone						
Lestor MacAldoff	841101	421100	5199800	68	50	20	44	5	5	0-2 Clay	80	63	66	68		
										2-68 Sandstone, some claystone						
Leo Myers	780920	421100	5199900	65	50	45	38	5	7	0-15 Clay and sand till	45	48	63	65		
										15-65 Sandstone and claystone						
Clare O'Shea	790924	421100	5200100	54	25	37	37	5	5	0-2 Clay	41	44	53	54		
										2-54 Sandstone and claystone						
Perry's Construction	791106	421100	5200100	58	50	25	41	5	7	0-2 Clay	48	51	56	58		
										2-58 Sandstone and claystone						
Bank of Commerce	811106	421100	5200100	100	50	35	75	5	10	0-3 Till	84	87	96	100		
										3-100 Sandstone and claystone						
Mrs. J.L. Arsenault	781113	421100	5200200	58	50	28	26	5	8	0-6 Clay	33	36	46	48	56	58
										6-58 Sandstone, some claystone						
Rev. Claude Shea	840503	421100	5200600	60	50	20	45	10	7	0-3 Clay	50	53	56	58		
										3-60 Claystone, some sandstone						
Perry's Construction	850723	421100	5200600	50	50	20	31			0-1 Clay	40	43	48	50		
										1-50 Sandstone and claystone						
John Perry	760610	421100	5200700	85	50	20	27	8	30	0-20 Clay	30	33				
										20-85 Sandstone						
Nelson Arsenault	851231	421100	5200800	57	50	22	31			0-2 Clay	42	45	55	57		
										2-57 Sandstone and claystone						
Orville Doucette	800714	421100	5201500	50	50	20	30	5	5	0-30 Sand and claystone	30	31	41	44		
										30-50 Sandstone, some claystone						
Tignish Co-op	720630	421102	5200000	154	45	27	92	12	10	0-17 Sand	110	115	145	150		
										17-154 Sandstone, some claystone						

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Tignish Sport Ass.	721118	421199	5199883	70	60	18	25	12	15		
Roland Paynter	770705	421200	5199100	70	25	20	28	8	10	0-10 Sand till 10-70 Sandstone, some claystone	40 40 60 65
Tignish Legion	811029	421200	5199800	80	60	28	43	5	10	0-5 Till 5-80 Sandstone, some claystone	63 66 78 80
Edmund Gallant	770829	421200	5200000	60	60	25	43				
Elyre Bernard	770826	421200	5200000	60	60	20	36				
C.N.R. Station	780809	421200	5200100	66	55	50	59	8	6	0-12 Till 12-66 Sandstone and claystone	
Arsenault	801112	421200	5200700	57	60	15	28	5	5	0-3 Clay 3-57 Claystone and sandstone	28 29 42 45 55 57
Ronald Perry	630330	421300	5200800	56	60	20	35	5	5	0-3 Clay 3-56 Sandstone, some claystone	40 43 53 56
Aubrey Arsenault	781000	421200	5200800	70	60	15	30	8	10	0-9 Sand till 9-70 Sandstone, some claystone	35 40 60 65
Henry Doucette	810417	421200	5201900	75	60	30	58			0-3 Clay and sand 3-75 Claystone and sandstone	74 77
Bruce Arsenault	721004	421201	5199882	61	20	14	21	8	15	0-7 Clay till 7-61 Sandstone	28 31 57 60
Leonard Bernard	721110	421203	5200882	36	60	15	17	5	1		17 18
Irving Oil Garage	700818	421280	5200050	141	60	38	87	8	15	0-23 Sand and sandstone 23-141 Sandstone and claystone	95 98 135 138
Delorme Richard	860813	421300	5199800	80	35	22	38			0-2 Clay 2-80 Sandstone and claystone	48 51 58 60
Alfred Gallant	781125	421300	5199800	55	60	35	25	5	5	0-10 Clay and sand 10-55 Sandstone and claystone	25 28 31 34 54 57
Tignish Sport & Rec.	851028	421300	5199800	80	50	25	34			0-2 Clay 2-80 Sandstone and claystone	45 48 60 63 75 78
William Handrahan	770725	421300	5199800	70	60	13	34	8	10	0-11 Sand till 11-70 Sandstone, some claystone	55 65

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Trail Cameron	791003	421300	5199900	85	50	45	70	5	10	0-2 Clay 2-85 Sandstone, some claystone	75 78
Fred Martin	821116	421300	5199900	85	50	30	68	5	10	0-3 Clay 3-85 Sandstone, some claystone	72 75 83 85
John Perry	770830	421300	5200000	70	50	30	39				
Claude LeClair	780915	421300	5200200	50	50	32	35	5	5	0-10 Clay and sand till	45 48
John Hackett	821120	421300	5200300	75	50	20	50	5	5	10-50 Sandstone and claystone 0-3 Clay	63 65 72 75
Senior Citizens	841121	421300	5200600	105	50	20	42	50	30	3-75 Sandstone and claystone 0-8 Sand till	50 60 90 100
John Gaudet	760706	421300	5200600	19	50	13	16			8-105 Sandstone, some claystone 0-16 Sand and clay	17 19
John Perry	711112	421300	5200694	60	40	20	21	8	1	16-19 Sandstone 0-19 Clay till	
David Harper	770120	421300	5201900	58	50	19	31	8	10	19-60 Sandstone and claystone 0-9 Sand till	40 50
John Perry	711110	421301	5200993	59	40	15	32	8	1	9-58 Sandstone, some claystone 0-25 Clay till	
Leonard Perry	721106	421301	5201292	62	60	20	21	8	15	25-59 Sandstone, some claystone 0-5 Clay till	30 33 58 61
John Perry	711105	421302	5201094	58	40	12	18	10	1	5-62 Sandstone 0-16 Clay till	
Vernon Gaudet	700602	421330	5200050	90		15	63	6		16-58 Sandstone 0-58 Clay	
Stanis DeRoches	781129	421400	5199800	68	50	40	50	5	8	56-90 Sandstone 0-6 Clay	67 68
Paul McAlduff	781016	421400	5200800	74	50	22	35	12	10	6-68 Sandstone, some claystone 0-14 Sand till	40 48 60 70
Leonard Alyward	721005	421400	5201392	60	55	11	25	8	15	14-74 Sandstone, some claystone 0-12 Sand till	29 54
Gratton McHugh	710505	421420	5199780	45	50	4	24			12-60 Sandstone 0-6 Clay till 6-45 Sandstone, some claystone	

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Perry's Construction	771218	421450	5200650	60	50	15	35	7	8	0-8 Till 8-60 Sandstone, some claystone	54 57
Bernard Harper	810820	421500	5199500	67	25	28	38			0-3 Clay 3-67 Sandstone, some claystone	50 53 64 67
Arsene Gallant	851008	421500	5199800	55	50	22	40			0-2 Clay 2-55 Sandstone and claystone	46 48 52 55
Edward Gavin	731130	421500	5200100	60	30		30				
John Perry	770527	421700	5200100	53	30	10	22	10	30	0-18 Clay till 18-53 Sandstone	
Lloyd Mackay	851001	421800	5198700	68	50	24	51			0-3 Clay 3-68 Sandstone and claystone	56 59 66 68
Patsey Powers	780807	422100	5200800	50	25	25	28	5	307	0-3 Clay 3-50 Sandstone and claystone	30 33 41 44
Michael Callahan	781006	422100	5200800	53	25	35		5	5	0-7 Clay and sand 7-53 Sandstone, some claystone	35 38 51 53
M. Gallant	720719	423400	5200300	61	27		21	8	15	0-3 Clay 3-61 Sandstone, some claystone	29 57
Wilfred Vend	780903	423400	5200300	27	25	8	18	10	1	0-18 Sand and claystone 18-27 Sandstone	25 27
Robert Hogan	720906	422500	5200400	62	25		27	8	15	0-7 Sand 7-62 Sandstone	33 36 56 59
			Averages	55		24	35	8			

APPENDIX II

WATER QUALITY DATA

APPENDIX II
Water Quality Analyses
TIGNISH

Name&Date		Easting/Northing	Parameters Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	pH	Fe (T)	Fe (D)	Mn	Cd	Cu	Cr	Ni	Pb	Zn
C. Bernard	791213		73.0	16.00	50.0	8.30	248.0	205	81		0.06	4.9	7.3	< 0.1	< 0.1	< 0.02		0.05				0.10
Edgar Bernard	861124	421700/5200100	44.1	9.98	18.7	1.42	152.1	114	40		0.07	3.5	7.9	< 0.1	< 0.1	< 0.02		< 0.02			< 0.1	0.49
Edgar Bernard	871208	421700/5200100	49.8	11.28	19.5	1.50	171.2	114	45		0.28	3.8	7.7	0.9	< 0.1	< 0.02		0.04			< 0.1	0.19
Elizabeth Cann	850307	420850/5200700	15.6	1.95	8.3	7.40	48.2	69	16		0.10	0.8	7.0	< 0.1	< 0.1	< 0.02		< 0.02			< 0.1	0.84
Owen Chaisson	800417		80.0	10.00	92.0	1.90		85	45		0.06	0.4	7.5			< 0.02		0.02			< 0.1	0.80
Edward Doucette	860118	420600/5199500	45.0	3.49	22.0	1.18	127.1	127	45		0.06	3.3	7.5	< 0.1	< 0.1	0.05		0.04			< 0.1	0.03
H. Doucette	800717		20.0	1.60	9.0	1.05		47	21		0.15	2.9	8.1	< 0.1		< 0.02		< 0.02			< 0.1	0.25
Fire Dept.	830108	421150/5199800	77.3	13.08	35.4	2.00	247.0	158	50	30	0.05	4.8	8.0	0.1	< 0.1	0.06		< 0.02			< 0.1	3.10
Clifford Gaudet	840717	424100/5199400	52.6	7.95	58.0	3.04	184.7	145	80		0.04	8.0	7.1	< 0.1	< 0.1	< 0.02		< 0.02			< 0.1	0.30
Clifford Gaudet	860423	424100/5199400	56.9	8.58	47.9	2.85	178.8	145	50	28	0.02	9.0	7.2	0.2	< 0.1	< 0.02	< 0.02	0.02	< 0.05	< 0.05	< 0.1	0.80
Leo Gaudet	800401		25.0	14.00	7.0	1.60		84	15	7	0.08	1.1	7.6			< 0.02		0.90			< 0.1	0.25
L. Gaudet	800717		20.0	1.50	9.5	1.35		75	18		0.10	2.7	8.0	< 0.1		< 0.02		0.02			< 0.1	0.40
Peter Gaudet	800401		32.5	3.00	10.5	1.55		81	15		0.04	3.6	7.6			< 0.02		0.07			< 0.1	0.19
P. Gaudet	800717		30.0	2.00	10.0	2.75		66	34		0.15	2.8	7.8	< 0.1		< 0.02		0.03			< 0.1	1.16
Edward Gavin	780218	422150/5200220	53.0	4.00	9.5	0.50	153.0	115	22			1.1	7.5	0.4	< 0.1	1.02						
Ken Gavin	800417		45.0	2.00	9.3	3.05		89	17		0.06	1.1	8.0			< 0.02		< 0.02			< 0.1	0.90
Romey Gavin	870519	424100/5202400	20.2	8.36	23.7	4.06	86.4	31	38		< 0.02	6.0	6.6	0.2	< 0.1	< 0.02		0.04			< 0.1	0.80
John Hackett	821202	421240/5200200	45.0	7.20	6.3	1.36	140.0	111	25	25	0.08	3.9	8.2	0.5	< 0.1	0.07		0.02			< 0.1	0.06
Jimmy LeClair	821109	419700/5200000	40.0	0.76	10.2	0.93		113	18	6	0.06	0.9	8.0	< 0.1	< 0.1	< 0.02	< 0.02	0.03	< 0.05	< 0.05	< 0.1	0.03
Fred Martin	850625	421300/5199950	54.7	9.14	25.3	1.78	175.1	163	50		0.07	3.0	7.4	0.2	< 0.1	< 0.02		< 0.02			< 0.1	0.43
Paul McAlduff	780729	422130/5200600	30.0	2.50	10.0	2.20	96.0	58	20			11.0	7.7	< 0.1	< 0.1	0.03						
Mrs. C. Molder	850423	423200/5200290	30.0	2.79	23.4	2.01	86.8	108	50		0.10	1.8	6.9	< 0.1	< 0.1	< 0.02		0.03			< 0.1	0.14
Harvey Myers	780621	422160/5198700	58.0	5.00	43.0	1.70	150.0	95	65	32	0.12	10.0	7.4	0.1	< 0.1	0.10		< 0.02			< 0.1	0.16
Ronald Perry	841018	421250/5201850	56.7	4.31	7.6	1.08	161.7	144	16		0.12	< 0.2	7.9	< 0.1	< 0.1	0.58		0.03			< 0.1	0.72
Medical Centre	810722	421230/5200260	26.0	1.30	8.0	0.60	70.0	62	10	7	0.06	< 0.2	8.1	< 0.1	< 0.1	< 0.02		0.20			< 0.1	0.26
Medical Co-op	841009	420550/5199750	22.4	0.62	7.6	0.54	60.2	68	12		0.10	0.3	8.0	< 0.1	< 0.1	< 0.02		0.04			< 0.1	0.97
Medical Co-op	861104	420550/5199750	22.8	1.01	8.7	0.74	61.6	73	12		0.09	0.6	7.9	< 0.1	< 0.1	< 0.02		0.05			< 0.1	0.20
Medical Co-op	870804	420550/5199750	31.4	1.22	8.5	0.55	84.0	67	15		0.12	0.4	7.6	< 0.1	< 0.1	0.05		0.03			< 0.1	0.17
Elementary Sch.	840329	420880/5200140	25.8	2.95	10.1	0.80	76.8	81	15		0.12	1.7	8.0	< 0.1	< 0.1	< 0.02		0.03			< 0.1	0.04
High School	840329	421300/5200490	39.4	6.66	14.1	5.78	126.1	132	22		0.12	2.8	7.4	< 0.1	< 0.1	< 0.02		0.06			< 0.1	0.10
Elementary Sch.	850212	421300/5200490	26.4	3.51	10.1	1.00	81.0	85	17		0.10	1.7	7.9	0.3	< 0.1	< 0.02		< 0.02			< 0.1	0.29
Dalton Centre	850212	420880/5200140	39.5	6.53	12.7	4.04	126.2	129	19		0.08	2.5	7.8	< 0.1	< 0.1	< 0.02		0.05			< 0.1	0.34

Name&Date		Easting/Northing	Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	pH	Fe (T)	Fe (D)	Mn	Cd	Cu	Cr	Ni	Pb	Zn
Senior Clt.	810722	421230/5200260	27.0	2.00	8.0	0.80	76.0	65	11	9	0.08	1.1	7.8	< 0.1	< 0.1	< 0.02		0.16			< 0.1	0.15
Sr Clt.- A (C)	841213	420630/5199780	32.2	2.49	9.6		90.7															
Sr Clt.- A (H)	841213	420630/5199780	11.0	0.39	55.0		29.1															
Senior Clt.- B	850226	421300/5200510	23.5	2.52	8.7	0.81	69.6	75	12		0.10	1.3	7.8	< 0.1	< 0.1	0.02		0.03			< 0.1	0.21
Sr Clt.- A (C)	850606	421100/5200211	6.9	0.27	55.0	0.17	19.5	75	13		0.24	1.0	7.8	< 0.1	< 0.1	0.02		< 0.02			< 0.1	0.63
Sr Clt.- B (H)	850606	421100/5200211	0.8	0.47	60.0	0.17	4.2	72	13		0.12	1.4	7.9	< 0.1	< 0.1	< 0.02		0.02			< 0.1	0.04
Senior Clt.- A	870604	420630/5199780	30.6	2.56	9.2	0.81	87.4	75	12		0.14	1.4	7.3	0.3	< 0.1	0.12		0.06			< 0.1	0.06
Senior Clt.- B	870604	420630/5199780	32.3	4.34	9.3	0.89	96.9	70	13		0.14	1.0	7.5	< 0.1	< 0.1	< 0.02		< 0.02			< 0.1	0.11
		CDWS							250	500		10.0	6.5-8.5	0.3		0.05	0.005	1.00	0.05		0.05	5.00